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CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART II . UNDERGROUND EXCAVATION IN ROCK

Section 2 Ventilation, Lighting, Mucking and Dewatering

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART II UNDERGROUND EXCAVATION IN ROCK

Section 2 Ventilation, Lighting, Mucking and Dewatering

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TO

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PRACTICE FOR CONSTRUCTION OF TUNNELS

PART II UNDERGROUND EXCAVATION IN ROCK

Section 2 Ventilation, Lighting,
Mucking and Dewatering

Alteration

(First cover page, pages 1 and 3,
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PART II UNDERGROUND EXCAVATION IN ROCK

Section 2 Ventilation, Lighting,
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(BDC 58)

Reprography Unit, BIS, New Delhi, India

Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART II UNDERGROUND EXCAVATION IN ROCK

Section 2 Ventilation, Lighting, Mucking and Dewatering

0. F O R E W O R D

0.1 This Indian Standard (Part II/Section 2) was adopted by the Indian Standards Institution on 15 March 1971, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The construction of tunnels involves a large number of problems because of the great longitudinal extent of the work and many kinds of conditions are encountered which for maximum economy should be treated differently. In view of this it has been appreciated that it would be futile to prepare a rigid set of rules or procedures which can be enforced without leaving any latitude for the exercise of discretion by the site engineer. The aim of this standard is to summarize the well known and proved principles and to describe the commonly used procedures and techniques for providing guidelines which would permit the site engineer to use his discretion. This section deals with the requirements for ventilation and lighting and procedures of mucking and dewatering for excavation of tunnels in rock. The Indian Standard Code of Practice for Construction of Tunnels (IS : 5878) is being published in parts and Part II in sections.

0.3 Section 1 of this part covers drilling and blasting, and section 3 tunnelling method for steeply inclined tunnels, shafts and underground power houses.

0.4 Other parts of this standard are as follows:

- Part I Precision survey and setting out
- Part III Underground excavation in soft strata
- Part IV Tunnel supports
- Part V Concrete lining
- Part VI Steel lining
- Part VII Grouting

0.5 This standard is one of a series of Indian Standards on tunnels.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part II/Section 2) deals with ventilation, lighting, mucking and dewatering for excavation of tunnels.

2. SAFETY REQUIREMENTS

2.1 Adequate safety requirements, in regard to ventilation, lighting, mucking and dewatering, shall be taken as specified in IS : 4756-1968†.

3. VENTILATION

3.1 Necessity—The purpose of ventilation in tunnels is to make the working space safe for workers by keeping the air fresh and respirable, free from harmful obnoxious gases and dust. Ventilation also serves the purpose of bringing down high temperatures (especially at the working face) due to diesel engines working inside the tunnel.

3.2 Mechanical ventilation shall be adopted to force the air in or out from the working-face through ventilation ducts.

3.3 Minimum requirements of purity of air, dust control and volume of air shall be in accordance with IS : 4756-1968†.

3.4 Methods—The following three methods are normally used for mechanical ventilation:

- a) Blowing in fresh air by ducts to the face of tunnel,
- b) Exhausting foul air by ducts from the face of tunnel so that fresh air is supplied *via* the tunnel itself, and
- c) Combination of blowing in and exhaust system.

3.4.1 The method of ventilation by blowing in fresh air is a positive means of supplying fresh air to the working face. However, the location of the air intake shall not be such as would short circuit foul air coming from the tunnel. It is the most convenient method of ventilation during drilling

*Rules for rounding off numerical values (revised).

†Safety code for tunnelling work.

and mucking operations, when persons working at face require fresh air. However, this method has a disadvantage that the foul air while being expelled through the tunnel, itself makes the approach to the working face from the portal rather unhealthy with poor visibility.

3.4.2 The method of ventilation by exhausting foul air is useful after blasting when it is desirous that blasted fumes should be removed expeditiously without being diffused along the whole length of tunnel. The location of the exhaust shall be such as not to pollute the air going into the tunnel. However, this method has a disadvantage that the fresh air while travelling along the length of tunnel absorbs heat moisture and foul gases of the hauling equipment resulting in an unpleasant working condition at face.

3.4.3 In the method of simultaneous exhausting and blowing, two systems of piping are required with their own independent mechanical blowers. The exhaust system will have a larger capacity, whereas the blowing system may have smaller diameter duct, sufficient for providing enough fresh air to workmen on face of tunnel. However, this method requires complete duplication of ventilation system and would be impracticable unless the driven tunnel is very long.

3.4.3.1 In practice the combined system of ventilation may be achieved by exhausting the gases after blasting and for all other operation using blowing in system. This may be achieved by providing reversible ventilation fans, whereby with the same installation of ducts and blowers the exhausting and blowing in air may be achieved.

3.5 Ducts—Ventilation ducts may be either of fabric or of metal.

3.5.1 Fabric ventilation ducts made out of high resistant nylon can only be used for blowing system as during suction the fabric would collapse.

3.5.2 Metal ducts shall conform to IS : 655-1963*.

3.5.3 Duct line may be laid either on the floor or hung from the side wall excavation depending on convenience and other economic aspects of ventilation. However, care shall be exercised to see that all the joints of duct line are air-tight to avoid losses due to leakage.

3.6 Ventilation Shafts—These may be provided at the intermediate section of a tunnel or at the extreme end of the underground work, say power house, after studying the economics of the same.

3.7 Fans—Ventilation fans can be of numerous types, such as non-reversible or reversible, externally driven or internally driven type. However, reversible type axial blowers with fan fitted directly on totally enclosed electric motor is recommended for ventilation of tunnels. It is a normal practice to fit two such units in one shell to increase the total output.

*Specification for metal air ducts (revised).

3.7.1 In the use of ventilation system the pressure under which the air is to be pumped into the tunnel may be mentioned. The diameter of pipe shall be fixed after taking into account the frictional resistance of air flow through the pipes and other relevant factors. Some length of the air duct near the working face should be kept flexible. For longer length of tunnel, addition of boosters at a suitable place may be necessary. For some length from the portal no elaborate ventilation system is necessary for excavation of tunnel.

4. LIGHTING

4.1 Adequate lighting shall be provided at the face and at any other point where work is in progress, at equipment installations, such as pumps, fans and transformers. A minimum illumination of 100 lux shall be provided at tunnel and shaft headings during drilling, mucking and sealing. When mucking is done by tipping wagons, running on trolley tracks, a minimum of 50 lux shall be provided for efficient and safe working. Along the length of the tunnel also adequate lighting shall be provided.

4.1.1 Any obstructions, such as jumbo, form work, etc, inside the tunnel shall be well lighted to avoid accidents when hauling units are moving.

4.1.2 Lighting at the working face shall be profuse. However, no single light shall be so powerful as to cause temporary blinding effect when looked at.

4.2 Voltage of supply line may be reduced in the tunnel from 230 V to 110 V for lighting purposes, where practicable. For motors of 440 V waterproof cables shall be laid in tunnels.

4.3 Incandescent lamps should be fixed in the centre of the roof of tunnel. In case the lamps are to be fixed on sides of tunnel, they shall be as high as possible and well above the ventilation ducts, so that the shadow of the duct is not formed on the road surface.

4.4 The electric circuits of the lighting in tunnel shall be divided into number of independent circuits with their isolators and fuse boxes separate. With the separation of the circuits, the repair works on the electric lighting system can be easily done by switching off the desired circuit while the other circuits are still in operation.

4.5 In addition to the fixed lighting system, all hauling equipment shall have their own lighting system. These lights not only give indication to the personnel in the tunnel of the approach of the hauling equipment but also permit them to negotiate the tunnel without any danger in case of emergencies when the fixed light systems are turned out.

4.6 In addition to the normal lighting, provision of flood lights shall be made at suitable intervals for detailed inspection for any particular length or spot.

5. MUCKING

5.1 The hauling equipment may be classified into the following major categories:

- a) Hauling on rails,
- b) Hauling on pneumatic tyres, and
- c) Other equipment like conveyors.

5.1.1 The choice of the equipment will, however, depend on numerous factors, such as shape, size and slope of tunnel, type of loading equipment available and the overall economy on the construction of the particular job.

NOTE 1 — The hauling system on rails is the oldest system used. Its advantage is that once the rails are laid, the hauling equipment, that is, wagons can be pulled on the track by locomotives requiring lesser horse power. It is, in fact, the cheapest mode of hauling. However, it has one basic disadvantage, that is, it has no flexibility of movement as the wagons have to move on fixed rail system only. This system can be conveniently used where the hauling grade is either fairly level or where the grade is very steep. In the former case, locomotives are used, while in the latter case haulage winches are used. Suitable arrangements for car changes, points and crossings, etc, would, however, be required in this case.

NOTE 2 — With large diameter tunnels, the haulage equipment on pneumatic tyres such as dumpers are best suited for the job. In view of restriction of space, the dumpers are of reversible type, or articulated type, so that the equipment does not have to take any turning inside the tunnel. Various models of reversible type and articulated type dumpers suited for tunnels are in the market, however, choice of the dumper will also depend on the loading equipment used inside the tunnel.

5.2 Capacities of the various loading equipment may be fixed depending upon the following:

- a) Combination of units and time cycle;
- b) Factors influencing the loading capacity, such as type of material excavated, working conditions, efficiency of the operator, condition of the machine, swing-angle of the machine, etc;
- c) Struck capacity and heaped capacity;
- d) Rock bodies for trucks and dumpers impact factors, etc; and
- e) Belt conveyors and the type of loaders that go with belt conveyors.

5.3 Loading equipment in tunnel may be subdivided into many types depending on the mode of travel, type of loading mechanism or mode of power.

5.3.1 On the basis of its mode of travel the type of loading equipment may be classified as:

- a) rail mounted,
- b) crawler mounted, and
- c) pneumatic-tyre mounted.

5.3.2 On the basis of its loading mechanism, the types of loading equipment may be classified as:

- a) front end loaders,
- b) overhead rocker shovels, and
- c) short boom shovels.

5.3.3 On the basis of its motive power, the loading equipment may be classified as:

- a) pneumatically driven,
- b) diesel driven, and
- c) electric driven.

5.3.3.1 In all conditions the hauling equipment and the loading equipment may be either driven by diesel, electricity or compressed air.

5.3.4 Diesel power is predominantly used for two main reasons, namely, cheapness in operation and absence of carbon monoxide in the exhaust. While diesels generate no carbon monoxide, their fumes are nauseating to breath ; therefore, a tunnel has to be well ventilated, if diesel locomotives are used. Petrol driven engines shall not be used in any case as prime mover in any underground works, as they generate carbon monoxide.

NOTE — Now electric driven loaders as well as locos including those driven by batteries are available. When electric power is used for loading and traction, tunnels remain much cleaner.

5.4 In small size tunnels and in shafts manual loading may be resorted to. For final cleaning after every blast also manual loading should be used.

5.5 The muck shall be dumped and spread evenly in the dump areas.

6. DEWATERING

6.1 Water that accumulates in a tunnel shall be effectively removed either by gravity flow or by pumping depending on conditions and circumstances met with.

6.2 When the tunnels are driven up grade with sufficient slope, the water may be removed from the tunnel through drains normally excavated on the sides of tunnel.

6.3 Extra quantity beyond the payline shall not be specifically excavated for forming drains. Usually the removal of bottom excavated muck to form drain is sufficient for the purpose. The position of the drain will solely depend on site conditions and the type of hauling equipment, the drains shall be placed on the side only, so that the road way can have proper camber.

6.4 Where the tunnel is being driven on flat gradient or downward gradient, the water accumulated shall be pumped out. Depending on the length of the tunnel and the gradient driven, the pumping may be either made in a single stage or in multi stage with balancing suction tank for each stage. The choice of number of pumping stages will depend on economy based on numerous factors.

6.4.1 However, such balancing suction tanks shall be situated at heavy leakage points. With this arrangement, the leakage water accumulated locally should be pumped or fed by gravity, if possible, into balancing tanks from where the water may be pumped through the main multi stage pumping system.

6.5 The pumping equipment required for dewatering shall be of the type which is non-clogging as the water pumped is heavily charged with dust particles, especially the drilling dust.

6.6 The following two main types of pumps are normally used for tunnel dewatering:

- a) Centrifugal pumps with open impellers (non-clogging type), and
- b) Pneumatic sludge pumps.

6.6.1 The motive power for centrifugal pumps may be either electrical or pneumatic motors. Diesel motive power is not preferable due to fumes and consequent extra load on the ventilation system.

6.6.2 The centrifugal pumps may be of various types, such as suction type or submersible, that is, with positive suction and with the prime mover also submersible without being damaged by water.

6.6.3 All dewatering at the working face of the tunnel shall be carried out by means of pumps driven by pneumatic motors. The electric motors may give out strong leakage currents which is hazardous at face where electric short firing is resorted to.

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